ATOMIC, MATTER-WAVE ROTATING SENSORS: NEW TECHNOLOGIES OF ATOMIC GYROSCOPES

Matter Wave Gyroscopes

Matter wave gyros, as in the case of optical gyros, use the Sagnac effect to detect rotation. A phase shift arises when the matter-wave interferometer rotates. Such phase shifts generally vary with the mass and are inversely proportional to the velocity of the interfering particles.

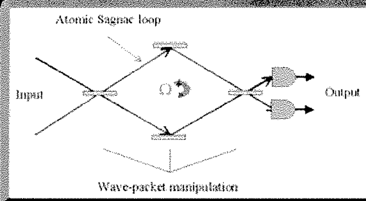
If two identical waves circulate in opposite directions along a closed path undergoing rotation Ω, then the beam traveling in the same direction as the rotation takes longer to travel around the path than the other beam, resulting in a phase shift Φ of interference pattern

$$\Phi = \left(\frac{4\pi m A}{h}\right)\Omega$$

where A is the area enclosed by the path, m is the mass of interfering particles, and h is the Planck constant.

Matter Wave Interferometers

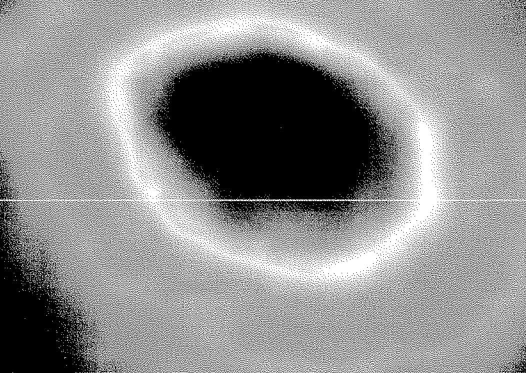
The key element of any gyro based on the Sagnac effect is an interferometer. The interferometer is composed of a wave source, two beam splitters, two mirrors and detectors.



Two-photon Raman transitions can be used to manipulate the atoms of the beam. With the Raman method, two counter propagated laser beams with a frequency difference $\omega_1 - \omega_2$ are chosen to be resonant with the transition between two atomic ground-state levels. Then light-atom momentum exchange can be used to coherently divide or deflect the atomic beam, effectively creating beam splitters or mirrors.

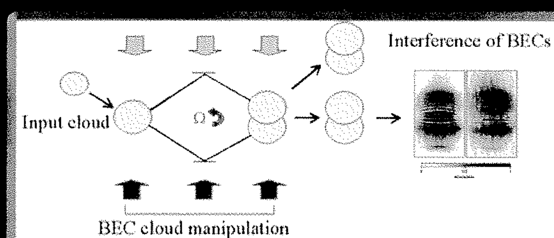
Cold Atom Manipulations

For the successful manipulations with atoms thermal effects must be suppressed. This can be done with three steps:
laser cooling,
atom trapping and
RF-evaporative cooling technique.



Here is how these technologies work:

The source of matter-waves, or atom laser, can be constructed using a collection of ultra cold atoms. An atom laser generates an intense coherent beam of atoms. The atom laser does for atoms (matter-waves) what an optical laser does for light (electromagnetic waves).



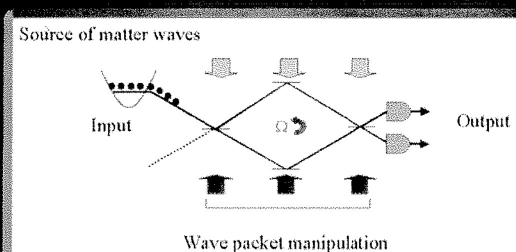
The interference of two condensate clouds can also be considered as a model of gyro based on a one-input port interferometer.

GYROS (in general)

Gyros are designed to define a fixed direction in space or to determine the change in angle or the angular rate with respect to a reference frame.

Gyros are used for guidance, navigation, and stabilization of the flight trajectories; to determine the heading and orientation of a spacecraft during and after a series of maneuvers; or to stabilize itself and aim its instruments.

Gyros use different physical phenomena to respond to input angular rates. Thus, spinning mass gyros sense changes in angular momentum. Instruments that do not have spinning masses are not technically gyros, but angular rate sensors. However, the term gyro is commonly used for all rate sensing devices. Optical and matter wave gyros sense phase shift of optical and matter wave beams due to rotation of the device.



BENEFITS

Novel technologies of matter wave interferometry with applications to the detection of the rotation rates have matured from research projects to useful tools only in the past few years. Advantages of matter wave gyros: (a) the inherent sensitivity of matter wave gyros exceeds that of a photon - based system by a factor of (m -is the atomic mass , is the photon frequency); (b) phase sensitivity is scaled down to O(1/N) (N is the number of atoms passing through the interferometer in unit time) for correlated-two-input-port atomic interferometers. At the present time matter, wave gyros have the potential to be the most sensitive rotation measuring sensors in development, and they have the capability of reaching sensitivities of 10-5 E.

ATOMIC, MATTER-WAVE ROTATING SENSORS: NEW TECHNOLOGIES OF ATOMIC GYROSCOPES

Matter Wave Gyroscopes

Matter wave gyros, as in the case of optical gyros, use the Sagnac effect to detect rotation. A phase shift arises when the matter-wave interferometer rotates. Such phase shifts generally vary with the mass and are inversely proportional to the velocity of the interfering particles.

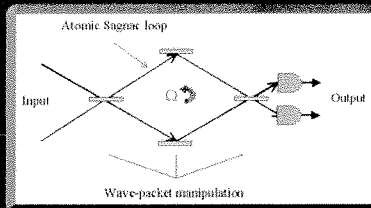
If two identical waves circulate in opposite directions along a closed path undergoing rotation Ω, then the beam traveling in the same direction as the rotation takes longer to travel around the path than the other beam, resulting in a phase shift Φ of interference pattern

$$\Phi = \left(\frac{4\pi m A}{h}\right)\Omega$$

where A is the area enclosed by the path, m is the mass of interfering particles, and h is the Planck constant.

Matter Wave Interferometers

The key element of any gyro based on the Sagnac effect is an interferometer. The interferometer is composed of a wave source, two beam splitters, two mirrors and detectors.



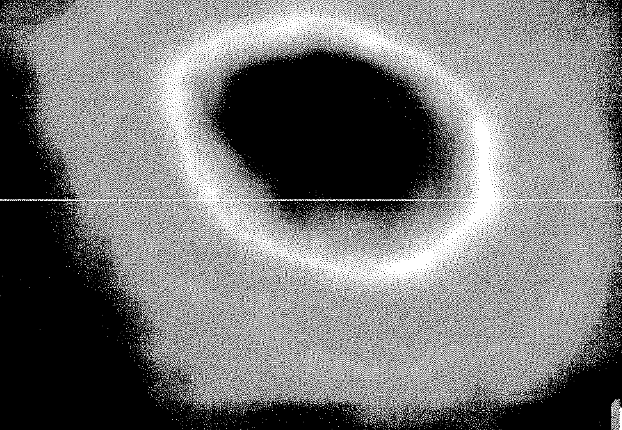
Two-photon Raman transitions can be used to manipulate the atoms of the beam. With the Raman method, two counter propagated laser beams with a frequency difference $\omega_1 - \omega_2$ are chosen to be resonant with the transition between two atomic ground-state levels. Then light-atom momentum exchange can be used to coherently divide or deflect the atomic beam, effectively creating beam splitters or mirrors.

Cold Atom Manipulations

For the successful manipulations with atoms thermal effects must be suppressed. This can be done with three steps:
laser cooling,
atom trapping and
RF-evaporative cooling technique.

Here is how these technologies work:

The source of matter-waves, or atom laser, can be constructed using a collection of ultra cold atoms. An atom laser generates an intense coherent beam of atoms. The atom laser does for atoms (matter-waves) what an optical laser does for light (electromagnetic waves).

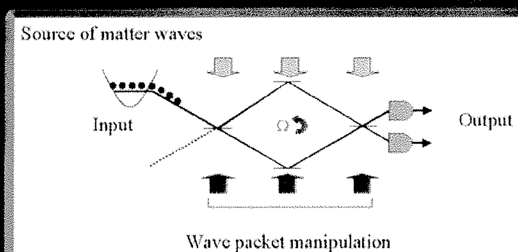


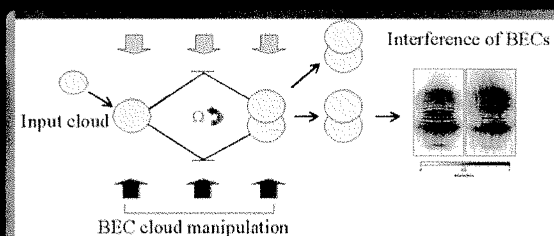
GYROS (in general)

Gyros are designed to define a fixed direction in space or to determine the change in angle or the angular rate with respect to a reference frame.

Gyros are used for guidance, navigation, and stabilization of the flight trajectories; to determine the heading and orientation of a spacecraft during and after a series of maneuvers; or to stabilize itself and aim its instruments.

Gyros use different physical phenomena to respond to input angular rates. Thus, spinning mass gyros sense changes in angular momentum. Instruments that do not have spinning masses are not technically gyros, but angular rate sensors. However, the term gyro is commonly used for all rate sensing devices. Optical and matter wave gyros sense phase shift of optical and matter wave beams due to rotation of the device.





The interference of two condensate clouds can also be considered as a model of gyro based on a one-input port interferometer.

BENEFITS

Novel technologies of matter wave interferometry with applications to the detection of the rotation rates have matured from research projects to useful tools only in the past few years. Advantages of matter wave gyros: (a) the inherent sensitivity of matter wave gyros exceeds that of a photon - based system by a factor of (m -is the atomic mass , is the photon frequency); (b) phase sensitivity is scaled down to O(1/N) (N is the number of atoms passing through the interferometer in unit time) for correlated-two-input-port atomic interferometers. At the present time matter, wave gyros have the potential to be the most sensitive rotation measuring sensors in development, and they have the capability of reaching sensitivities of 10-5 E.

ATOMIC, MATTER-WAVE ROTATING SENSORS: NEW TECHNOLOGIES OF ATOMIC GYROSCOPES

Matter Wave Gyroscopes

Matter wave gyros, as in the case of optical gyros, use the Sagnac effect to detect rotation. A phase shift arises when the matter-wave interferometer rotates. Such phase shifts generally vary with the mass and are inversely proportional to the velocity of the interfering particles.

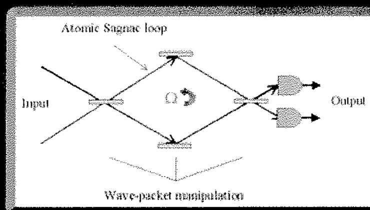
If two identical waves circulate in opposite directions along a closed path undergoing rotation Ω, then the beam traveling in the same direction as the rotation takes longer to travel around the path than the other beam, resulting in a phase shift Φ of interference pattern

$$\Phi = \left(\frac{4\pi m A}{h}\right)\Omega$$

where A is the area enclosed by the path, m is the mass of interfering particles, and h is the Planck constant.

Matter Wave Interferometers

The key element of any gyro based on the Sagnac effect is an interferometer. The interferometer is composed of a wave source, two beam splitters, two mirrors and detectors.



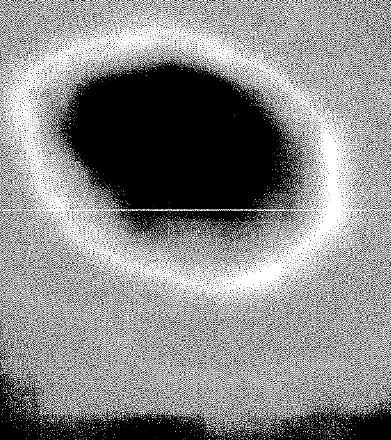
Two-photon Raman transitions can be used to manipulate the atoms of the beam. With the Raman method, two counter propagated laser beams with a frequency difference $\omega_1 - \omega_2$ are chosen to be resonant with the transition between two atomic ground-state levels. Then light-atom momentum exchange can be used to coherently divide or deflect the atomic beam, effectively creating beam splitters or mirrors.

Cold Atom Manipulations

For the successful manipulations with atoms thermal effects must be suppressed. This can be done with three steps:
laser cooling,
atom trapping and
RF-evaporative cooling technique.

Here is how these technologies work:

The source of matter-waves, or atom laser, can be constructed using a collection of ultra cold atoms. An atom laser generates an intense coherent beam of atoms. The atom laser does for atoms (matter-waves) what an optical laser does for light (electromagnetic waves).

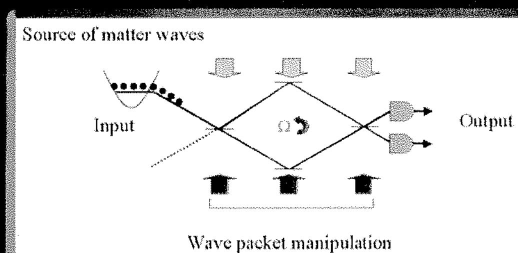


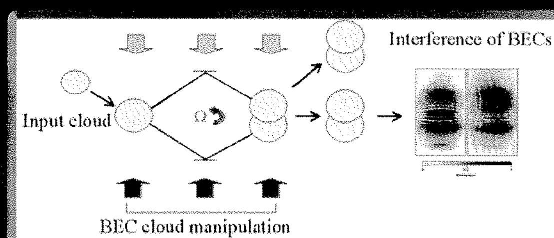
GYROS (in general)

Gyros are designed to define a fixed direction in space or to determine the change in angle or the angular rate with respect to a reference frame.

Gyros are used for guidance, navigation, and stabilization of the flight trajectories; to determine the heading and orientation of a spacecraft during and after a series of maneuvers; or to stabilize itself and aim its instruments.

Gyros use different physical phenomena to respond to input angular rates. Thus, spinning mass gyros sense changes in angular momentum. Instruments that do not have spinning masses are not technically gyros, but angular rate sensors. However, the term gyro is commonly used for all rate sensing devices. Optical and matter wave gyros sense phase shift of optical and matter wave beams due to rotation of the device.





The interference of two condensate clouds can also be considered as a model of gyro based on a one-input port interferometer.

BENEFITS

Novel technologies of matter wave interferometry with applications to the detection of the rotation rates have matured from research projects to useful tools only in the past few years. Advantages of matter wave gyros: (a) the inherent sensitivity of matter wave gyros exceeds that of a photon - based system by a factor of (m -is the atomic mass , is the photon frequency); (b) phase sensitivity is scaled down to O(1/N) (N is the number of atoms passing through the interferometer in unit time) for correlated-two-input-port atomic interferometers. At the present time matter, wave gyros have the potential to be the most sensitive rotation measuring sensors in development, and they have the capability of reaching sensitivities of 10-5 E.